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Energy Efficient Phones using Cloud

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***Abstract*—with the rapid development of mobile technology, smart phones are like today's computer. Smart phones provide all the features of computer with high processing speed and memory compared couple of years back. With the mobile networking development and capability of device, energy efficiency becomes an important design consideration due to the limited battery life of mobile devices. The emergence of mobile cloud has enabled the possibility of moving complex calculations and device operations to the "cloud" in an effective way. With cloud computing being implemented in mobile devices some of the primary constraints of mobile computing, such as hardware with less computational power and battery life, could be resolved by moving complex operations and computations to the cloud. In this paper it is discussed how cloud computing may provide energy saving to mobile users and hence increasing the battery life of the mobile using some mobile applications and compare the results to their non-cloud counterparts.**

***Index Terms*—Computation Offloading, Cloud Computing, Energy-efficiency, Mobile Cloud Computing.**

I. INTRODUCTION

With the advent of Cloud computing (CC), the possibility of moving complex calculations and device operations to the "cloud", or the internet, is a real possibility. Mobile devices have always been modest to PCs in terms of hardware. Merely not only with the rise of cloud computing, but more specifically mobile cloud computing (MCC), there is no reason for mobile devices to come in second place in terms of hardware any more.[7]

IJERT

The cloud computing model introduces a three layer structure, as shown in figure 1, to the way resources, services and applications are distributed. The bottom layer is the IaaS (Infrastructure as a Service) layer which represents the physical hardware that provides storage, computational power etc. This layer is practically invisible to application developers and end users and is meant to be managed automatically or by the IaaS service provider. The middle layer is the PaaS (Platform as a Service) layer which delivers functionality to developers. The PaaS layer services are essentially development platforms that let developers focus on their application instead of the physical hardware problem. The top layer is the SaaS (Software as a Service) layer where applications interface with end users. It is on this layer that the applications are accessed and used by its users, such as Facebook, Gmail, YouTube etc. which belong to the SaaS layer. Users do not need to know how the underlying hardware layer (IaaS) functions and they do not need access to development and deployment platforms in the PaaS layer.

The term mobile cloud computing began appearing soon after cloud computing gained some credibility. It is only logical that if you can offload expensive operations from computers, why not do it on mobile devices that are becoming increasingly similar to PC's? However MCC technology is faced with not only the standard concerns of cloud computing, but there are also the inherent connectivity problems.

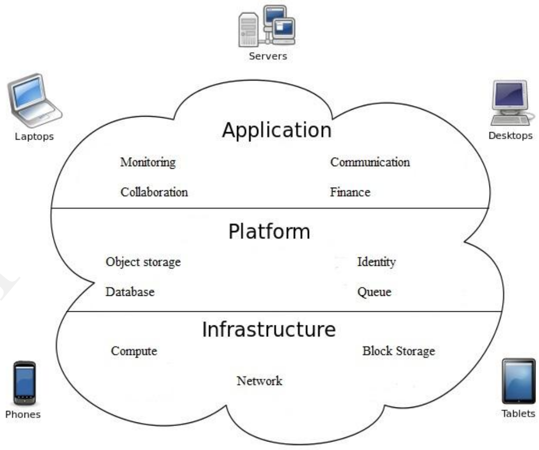

Figure 1. The 3 layers of cloud Computing

Cloud computing is a new paradigm in which computes resources such as memory, storage, and processing are not physically present at the user's location. Instead, a service provider will own and manage the various resources, and users try to access them via the Internet. For example, Amazon's Simple Storage Service (S3) allows users to store and perform computations on stored data using the Elastic Compute Cloud (EC2).

This type of computing provides many advantages for businesses including low initial capital investment, shorter time for new services, lower operation costs maintenance and maintenance, higher utilization through virtualization and easier disaster recovery that make cloud computing an attractive option. Reports say that there are several benefits in shifting computing from the desktop to the cloud. Similarly we can use cloud computing for mobile users. The main constraints for mobile computing are limited energy and wireless bandwidth. Cloud computing can provide energy savings as a service (EaaS) to mobile users, though it also poses some challenges.

In these days Mobile systems, such as smart phones, have become the primary computing platform for many users.

Different studies have identified longer battery lifetime as the most important feature of such systems. A 2005 study of users in 15 countries 3 found longer battery life to be more important than all other features, including cameras or storage. A survey last year by Change Wave Research revealed short battery life to be the most disappointed characteristic of Apple's iPhone 3GS, while a 2009 Nokia poll showed that battery life was the top concern of music phone and internet users.

Many applications are too computation mechanisms to perform on a mobile system. If a mobile user wants to use complex applications, the computation must be performed in the cloud. Other applications such as image retrieval, navigation, gaming, and voice recognition can run on a mobile system. However, they consume moderate amounts of energy. Can offloading this type of applications to the cloud save energy and extend battery lifetimes for mobile users? Low-power discussions have been an active research topic for many years. There are four basic approaches to saving energy and extending battery lifetime in mobile devices:

- ✓ *Adopt a new generation of semiconductor technology.* As transistors become smaller, each transistor consumes less power and as transistors become smaller, more transistors are needed to provide more functionalities and better performance; due to this, power consumption actually increases.
- ✓ *Avoid wasting energy.* Whole systems or individual components may enter standby or sleep modes to save power.
- ✓ *Execute programs slowly.* When a processor's clock speed doubles, the power consumption nearly octuples. If the clock speed is reduced by half, the execution time doubles and only one quarter of the energy is consumed.
- ✓ *Eliminate computation.* The mobile system does not perform the computation; instead, computation is performed somewhere else, it increases the mobile system's battery lifetime.

In this work we are concentrating only on the last approach for energy conservation. The main goal of this paper is to evaluate what kind of performance and features we can expect from a cloud based application on a mobile device, Different effects it will have on the device that runs it in terms of performance and power consumption, and to analyse various issues that can emerge when running cloud based applications on mobile devices.

II. LITERATURE STUDY

The primary constraints for mobile computing are limited energy and wireless bandwidth [1] and these constraints also apply to mobile cloud computing. Users needs to value longer battery life on mobile devices higher than most other features. The cloud based applications on mobile devices uses a technology such as offloading[2][3] that aims to have most, if not all, calculations and device operations done on a virtual machine in the cloud. This will result in less CPU usage and memory consumption [4] but will it also reduce power consumption on the device? Studies [5] have been conducted on power consumption for cloud and noncloud based applications on laptops and smartphones. The study compares power consumption of cloud and noncloud Based versions of three types of applications (word processing, multimedia and gaming). The results from these studies show that all three of the cloud based applications consume more power than their noncloud counterparts on smartphones while only the cloud based multimedia application consumed more power on a laptop. Both the cloud and noncloud based multimedia applications had similar power consumption when rendering the video on the device but the cloud based application used up more power because of the large amount of data that had to be transferred from the cloud. This is due to the fact that the Wi-Fi interface is a much bigger share of the power consumption in smartphones than laptops[5].

But a lot of progress has been made in wireless performance and there are several technologies that are believed to minimize the issues of high energy consumption. An example is the improvements that are being done to wireless data transmission. The energy efficient wireless data transmission mechanism, the total energy cost (including data traffic produced by network related applications and extra data traffic caused by task offloading) of mobile systems could decrease. [6]

Our study consists of a technical experiment where we compared power consumption of noncloud applications and their cloud based counterparts. We compared the cost of the extra network traffic that is required by cloud based apps to less network traffic and local processing that is used by traditionally designed apps. Seeing as the way smartphones are used varies a lot with demographics and age groups, this means that there are no definitive top five usage scenarios. In a study carried out by Comscore in 2012, it was revealed that in the U.S sending text messages is the dominant activity on smartphones. The same study reports that listening to music is also among the top activities. We have evaluated apps in the categories messaging, audio playback and video playback.

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growth of cloud solutions. In this paper we are aiming to find out the above issues.

III. METHODOLOGY

Advancements in computing technology have expanded the usage of computers from desktops and mainframes to a wide range of mobile and embedded applications, including surveillance, environmental sensing, GPS navigation, mobile phones, autonomous robots, etc. Many of these applications run on systems with limited resources. For example, mobile phones are battery powered. Environmental sensors have small physical sizes, slow processors, and small amounts of storage. Most of these applications use wireless networks and their bandwidths are orders-of-magnitude lower than wired networks. Meanwhile, increasingly complex programs are running on these systems—for example, video processing on mobile phones and object recognition on mobile robots. Thus there is an increasing gap between the demand for complex programs and the availability of limited resources.

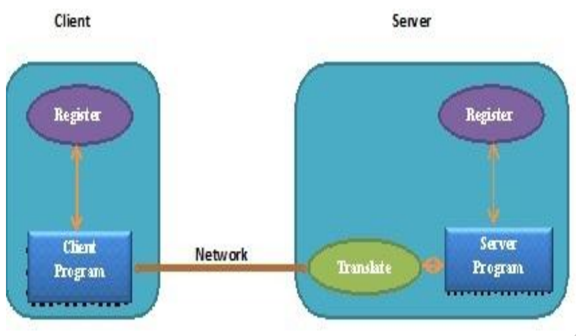

Figure 2: Computation Offloading

Offloading is a solution to augment these mobile systems' capabilities by migrating computation to more resourceful computers (i.e., servers) as shown in figure 2. This is different from the traditional client-server architecture, where a thin client *always* migrates computation to a server. Computation offloading is also different from the migration model used in multiprocessor systems and grid computing, where a process may be migrated for load balancing. The key difference is that computation offloading migrates programs to servers outside of the users' immediate computing environment; process migration for grid computing typically occurs from one computer to another within the same computing environment, i.e., the grid.

Our study consisted of few comparisons between traditionally designed, noncloud based apps and cloud based apps which could act as their replacements. To measure the power consumption we used Powertutor [8], an app developed by PhD students at the University of Michigan with the sole purpose of measuring power consumption of apps and system services and components on Android devices. When choosing the power monitor app we decided to go with the Powertutor app for Android because it seems to be the dominant choice when making power profiles for the Android platform, both for users and developers.

A. Experiment Process

To carry out the power measurement, first install the Powertutor application. For our experiment, we set the application to include network traffic and screen activity as part of the total power consumption of one application. Each part of the experiment was carried as described below:

1. Start the Powertutor application.
2. Make sure all the settings for the application are correctly set according to the above description.
3. Start the capture process.
4. Switch to the application being tested.
5. Carry out the tasks covered in the scenario description
6. Switch back to the Powertutor application and stop the capture process.
7. Examine the saved log file and extract the relevant data.
8. Calculate power in mW value using the following formula: mW = (J/t)*1000
(mW = milliWatt , J = Joule, t = Time in seconds)

B. Result Discussions

Our study will involve evaluating different cloud based mobile apps and comparing them with traditionally designed apps. Here we compared the cost of network traffic (where complex calculations are done in the cloud) to less network traffic and local processing. We have chosen to evaluate apps that offer the most common functionality that we think the average smartphone user desires. They are: Messaging, Video Playback and Music.

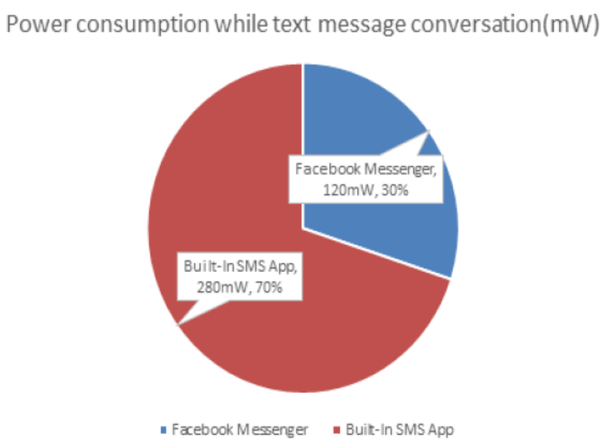

Figure 3. Power Consumption while video playback (mW)

Messaging:
The texting or messaging is one of the most common activities on smartphones of today. During our tests on messaging, the results showed us once more that the data transmission operations are not as costly as one can imagine. In messaging case, these costs are much lower than that of sending texts the "normal" way.

We found that using the Facebook messenger app saved maximum energy. This benefit, in conjunction with the fact that the Facebook messages are also free of charge and it is a

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highly desirable substitute for sending short text messages. The results for messaging are presented in figure 3.

Video Playback:
Whether it is recorded camera clips or movies, video playback is an often used feature in the smartphones of today.

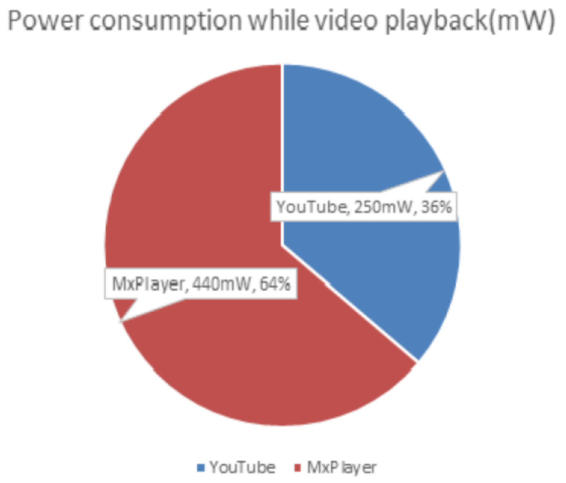

Figure 4. Power Consumption while video playback (mW)

We can see that playing video files is cheaper when done through streaming than playing back a locally stored file. This is because the more expensive operations such as decoding video/audio data can be offloaded to servers. When playing back a local file all this work has to be done on the device, which uses more power. The results for video playback are presented in figure 4.

Music:
Playing music is another essential feature of smartphones today. With the release of Spotify more and more people stream their music instead of storing it locally. However services such as iTunes still warrant a local music library which makes us think that the choice between local and cloud stored music libraries are interesting in this discussion. For the local music player we chose the native app which was installed on the phone called Walkman. In case of cloud based counterpart we chose the most common music streaming service is Spotify.

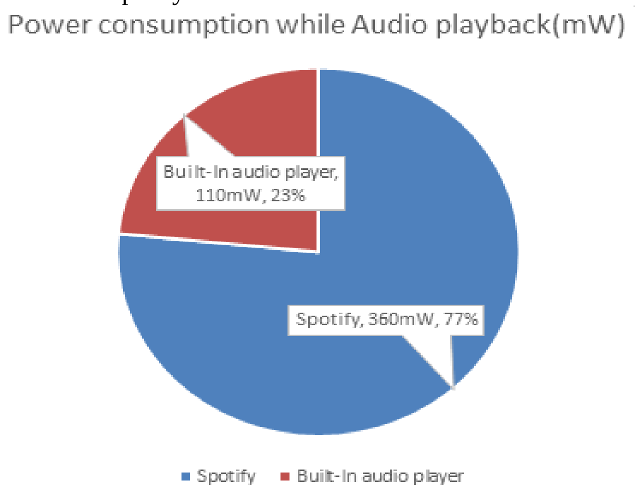

Figure 5. Power Consumption while audio playback (mW)

These results are an example of how far mobile cloud technology has come in less than a year. Namboodiri and Ghose (2012) [5] presented results that showed that cloud based video playback had a higher power consumption. The experiment shows a significant difference, because in our case, cloud based video playback consumed a lot less power. However our results in other parts of the experiment also show that some areas still aren't mature enough to warrant a complete reliance on cloud technology. In music playback we see that it is actually more costly to stream music than to play back local files. This is because the encoding/decoding process of simple mp3 files is cheaper than streaming the data via a network connection. There really isn't that much to gain from streaming lower quality music, besides obvious reasons such as saving storage space. The figure 5 shows the results for audio playback.
Cui et al. [6] (2013) proposed a model for reducing the cost of data transmission in mobile cloud solutions. This would potentially decrease power consumption, and in the case of audio streaming make it a more cost effective alternative than the local approach.

IV. CONCLUSION

The cloud computing paradigm enables the work anywhere anytime paradigm byallowing application execution and data can be stored on remote servers. This is very useful for mobile computing and communication devices that are constrained interms of computation power and storage. For users of such batterylife constrained devices, the most important criteria is the energy consumed by the applications they run. The aim of this work is to characterize under whatscenarios cloud-based applications would be relatively more energy-efficient forusers of mobile devices. In our experiments, as for messaging, the cloud based alternative Facebook messenger is cheaper both in terms of power and money, as individual messages are free of charge. Video playback using the official YouTube app is cheaper than playing back a locally stored file. This does not apply to music playback because the Spotify app is more costly than playing mp3 files from the device's storage.

As of now, fully migrating from all of your everyday applications to their cloud based counterparts will not result in longer battery life, as the alternatives only differ in some cases. What we can say that mobile cloud technology has matured within couple of years, and will probably continue to do so until it overcome the drawbacks of traditional approach. As cloud computing evolves further, mobile cloud computing will be the emerging trend and with cloud support apps such as WhatsApp, WeChat, Line and many more apps are very popular these days.

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